

CEMENT AND LIME

671.5
-EM
MANUFACTURE

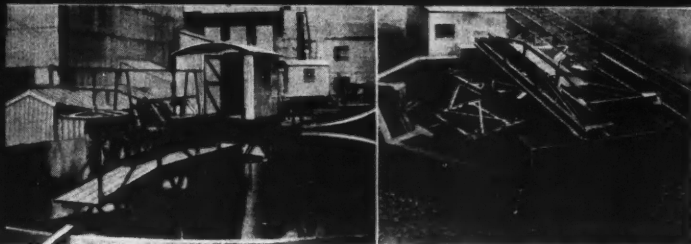
Vol. XV. No. 3

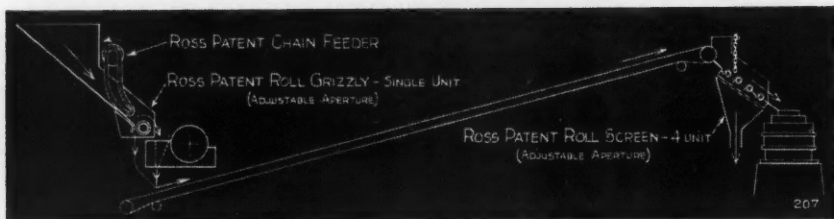
MARCH 1942

PRICE 1/- MONTHLY

**SLURRY PUMPS
SLURRY MIXERS
WASH MILLS**

**DESIGNERS
MAKERS AND
CONSTRUCTORS
of
COMPLETE PLANTS
FOR CEMENT MAKING**

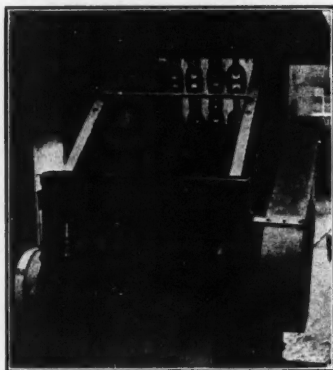
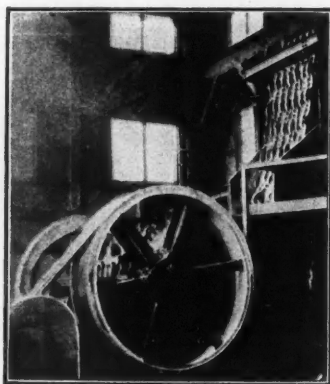




ROSS EQUIPMENT IN MODERN CRUSHING PLANTS

RIGHT at the first unit and at intermediate points in the plant, such as surge bin outlets and conveyor feeds, the **ROSS CHAIN FEEDER** provides a modern, highly efficient method of handling the material. Its flow control ensures increased production and greatly reduces maintenance and operating costs.

EQUALLY trouble-free and efficient are the **ROSS ROLL GRIZZLY** and the **ROSS ROLL SCREEN**—high capacity, long-life machines that are fundamentally immune from blocking or jamming. Even twisted scrap metal may be handled by them. An exact size product is passed by the apertures which, whether the machine is running or stationary, can be regulated over a wide range.



*Write to-day for the **ROSS SCREEN & FEEDER** literature*

ROSS ENGINEERS LTD.
2, VICTORIA ST., LONDON, S.W.1
ROSS SCREEN & FEEDER CO., 19, RECTOR STREET, NEW YORK CITY

CEMENT AND LIME MANUFACTURE

PUBLISHED 20TH OF EACH MONTH.

PRICE 1/- A COPY.

ANNUAL SUBSCRIPTION 12/- POST FREE

PUBLISHED BY
CONCRETE PUBLICATIONS LIMITED
14 DARTMOUTH STREET, LONDON, S.W.1

TELEPHONE: WHITEHALL 4581.

TELEGRAPHIC ADDRESS:
CONCRETIUS, FARN, LONDON

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"

"CEMENT & LIME MANUFACTURE"
"THE CONCRETE YEAR BOOK"
"CONCRETE SERIES" BOOKS, ETC.



VOLUME XV. NUMBER 3

MARCH 1942

Combustion in the Rotary Cement Kiln.

An article in this journal for September, 1941, dealt in a general way with the fuel consumption of the rotary cement kiln; the importance of low fuel consumption was stressed, but, apart from describing the Lepol and Calcinator kilns and mentioning the low fuel consumption obtainable with these units, no reference was made to the principles of combustion as practised in this type of kiln. In the December, 1941, number the difference between the wet and the dry process of cement manufacture was described in detail and the difference in the fuel consumption obtainable in these processes was described, but no reference was made to the process of combustion. Combustion in the rotary cement kiln differs from that of most, if not all, similar industrial furnaces in that it calls not only for a large quantity of heat, but for heat (or at least a large part of it) at the highest temperature possible under the conditions obtaining in kiln practice, and the design and arrangement of the parts near the combustion zone should enable the high temperature required to be obtained.

Reference was also made in these articles to low-grade and high-grade heat. These two conditions may be stated as follows: Low-grade heat is the condition or quality of heat that can be used for drying or heating the material and also for evaporating the slurry moisture; it may be assumed to range from the lowest usual temperature up to about 1,481 deg. F. High-grade heat is heat at above 1,481 deg. F., and which may extend to the highest temperature obtainable. The usual high limit of flame temperature obtainable in a rotary kiln is fully 2,500 deg. F., but flame temperatures have been recorded up to nearly 2,850 deg. F.; this higher temperature is actually attainable if the conditions are good, and it can be taken full advantage of under rotary cement kiln conditions.

In *Fig. 1* is indicated the length of a kiln, and the temperature of the gases as they are produced and as they pass along the kiln. The horizontal line at

1,481 deg. F. indicates the division between high-grade heat and low-grade heat. The highest flame temperature of the upper curve is 2,800 deg. F., and that of the lower curve 2,550 deg. F.; the lower temperature is that usually obtained and the upper temperature that which is possible when better conditions are provided and a higher standard of operation is obtainable. The upper curve is not only higher at the apex, but it is higher all through; the difference at the slurry end, however, is very small. The area between the two curves above the 1,481 deg. F. line is typical of the additional heat available, owing to the higher temperature, for the purpose of clinker production, without the use of additional fuel; the increase so far as clinker production is concerned is about 20 per cent.; this

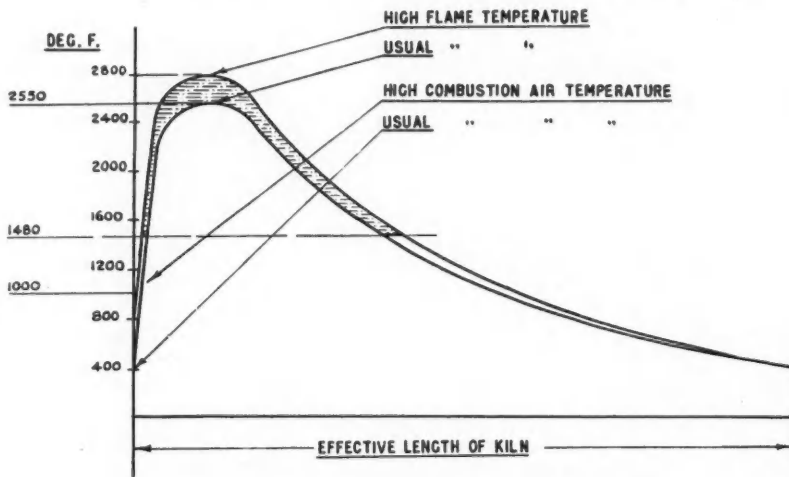


Fig. 1.—High Flame Temperature in the Rotary Kiln.

figure, however, is only illustrative and must not be regarded as exact. As the flame temperature and the average gas temperature for the full length of the kiln are higher, all the preparatory stages of the raw material (heating, drying, and de-carbonating), at least in part, are accelerated and the material is better prepared for the clinkering process. High flame temperature is most important in the process of clinker production, and it will be considered based upon coal having a heat value of 12,600 B.T.U.'s per lb.

High flame temperature calls for (1) the minimum amount of excess air; (2) the highest temperature of the combustion air; (3) perfect mixing of the gases; and (4) best combustion-zone conditions.

Excess Air.

The most economic amount of excess air may be considered to be, say, 5 per cent. above the theoretical figure. This should allow for any reasonable variation in the quality of the fuel and also for imperfect mixing of the gases,

and is nominally equivalent to 1 per cent. to 1.2 per cent. of oxygen in the waste gases. The avoidance of considerable excess air calls for careful control of the air supply, and this in turn demands attention to the air-seal rings at the firing end and to the hood or other cover. The arrangement of the kiln and the clinker cooler should also ensure that the whole of the secondary air passes through the cooler.

Flame Temperature.

Flame temperature is influenced considerably by the temperature of the combustion air, and a higher flame temperature will automatically result from a higher temperature of the combustion air providing nothing else conflicts with it or prevents full advantage being taken of the higher temperature. A typical mean figure for the temperature of the air used for combustion in rotary cement kilns would be, say, 400 deg. F., but, in view of the possible advantage of a higher temperature, there is every justification for this temperature being increased. The temperature of the primary or burner air and also the quantity may be a factor in the design of the coal plant or in the fineness of the ground coal, and requires separate consideration. Any considerable increase in the temperature of the secondary air would tend to earlier combustion and this might call for either a reduced quantity, or lower temperature, or higher velocity of the primary air. Adjustments of other details might also prove desirable or necessary, but the better results possible make the matter worth trying out; a review of all the existing and proposed conditions would be necessary.

Gas Mixing.

Perfect mixing of the gases, with a restricted amount of air, is very essential for good combustion, and this at first sight appears difficult to obtain. The usual kiln condition is that of a rich core of an air-coal mix at a rather low temperature surrounded by an annulus of secondary air at a considerably higher temperature, and possibly no real attempt to secure good mixing has been made before the flame is reached.

Combustion Zone Conditions.

It is readily understood that heat will pass from a hot body to a cooler, but remote, body by means of heat rays; it is not so fully appreciated that a chilling effect may be transmitted by cold rays from a cold body to a hot one. Cold-ray chilling may possibly occur at the same rate as hot-ray heating if the temperature difference is the same or comparable. Owing to this possibility the flame area should be protected from the chilling effect of cold rays from low-temperature surfaces near the flame. The inner metal surfaces of or in the combustion zone, the end cover or door of the kiln and the kiln hood, should all be covered or lined with firebrick or equal to ensure as far as practicable against heat loss or cooling. Any surface that would tend to radiate cold rays towards the flame should be kept at the highest temperature possible under the conditions.

A new type of air heater is stated to be in process of development in the United States. This comprises a jacketed extension to the lower end of the kiln shell; the extension piece is 4 ft. or 5 ft. long and the secondary air is passed through

this jacket on its way to the combustion zone. This arrangement serves its purpose as a heater quite well, but the chilling effect on the flame of the cold metal surface, with resultant lowering of the flame temperature, may result in a loss greater than the gain brought about by the higher temperature of the air. The gain due to the latter can be ascertained, but the reduced temperature of the former cannot be known. Air heating is a correct procedure, but it should be effected outside the kiln and not the inside, which should be kept as hot as practicable.

Heat transfer under rotary kiln conditions is effected primarily by radiation and convection and, as stated, calls for high flame temperature; this in turn requires good combustion and good combustion-zone conditions. But temperature

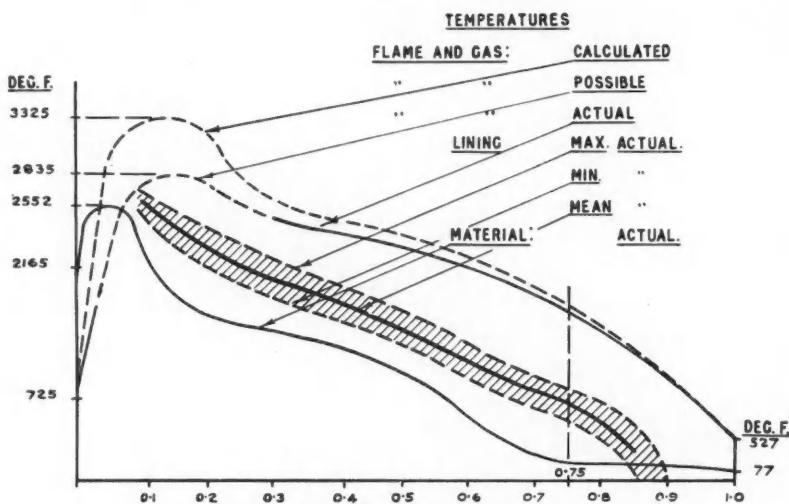


Fig. 2.—Rotary Kiln Temperatures.

falls at every stage of the process, and the design of the parts of the combustion zone and the control of the process should ensure that temperature fall is the lowest practicable at every point.

Fig. 2 has been amplified and re-drawn from *Cement and Lime Manufacture* for February, 1938, to illustrate this temperature drop and temperature difference. The original diagram was based on data obtained during a careful test upon a cement kiln, and the results given should be above question. A summary of the points to be noted in connection with the diagram is as follows :

- (1) The *calculated* temperature of the flame and the gas is shown by a dotted line for the full length of the kiln.
- (2) The *possible* flame temperature is shown by a heavy dotted line and the *actual* gas temperature by a full line. It will be noted that a consider-

able difference occurs between the calculated gas temperature and the actual temperature at the early part of the cycle, but they almost coincide at the slurry end of the cycle.

(3) The highest flame temperature is indicated at 2,835 deg. F. (1,558 deg. C.); this, if correct, is a good figure though it is a long way below the calculated temperature of 3,325 deg. F. (1,830 deg. C.). The highest temperature of the material, namely, 2,552 deg. F. (1,400 deg. C.) tends to be low, or at any rate it could with advantage be somewhat higher. The temperature of the clinker as discharged is 2,165 deg. F. (1,185 deg. C.) and that of the combustion air 725 deg. F. (385 deg. C.); these appear satisfactory as far as the conditions are known.

(4) The temperature of the lining at any section varies by an average of about 360 deg. F. during each revolution of the kiln. The upper part of the lining, uncovered for the time being, takes up heat from the gases and gives up heat to the material later when it is in the lower position and covered.

(5) Although the lower part of the bed of material is in constant engagement with the lining, and although the upper surface of the material is being constantly scrubbed by the hot gases, the mean temperature of the material is between 1,000 deg. F. and 1,200 deg. F. below that of the gases for the greater part of the length of the kiln.

(6) The temperature of the gases falls very rapidly from position 0.75 to the end of the kiln; this point is that at which the chain system commences.

Good combustion conditions in a rotary kiln, owing to the many factors involved, can only be obtained and maintained by ensuring one or more basic conditions. General experience indicates that it is best for the speed of the kiln and the rate of slurry feed to be kept constant, subject to nothing abnormal arising that conflicts with this requirement.

The normal rate of downward movement of slurry and material in a kiln 8 ft. net diameter, having a slope of 1 in 25, and rotating at the rate of one revolution per minute would be 12 in. per revolution, or, say, 1 ft. per minute. If the kiln were 230 ft. long the slurry and material would require, say, from $3\frac{1}{2}$ to 4 hours to pass from the slurry stage to the fully-burnt clinker stage. Any large-diameter zone would increase the rate of passage, but the greater volume at this part, owing to the increased diameter, would nullify or reduce the movement increase. Any change in the rate of slurry feed would not therefore call for any change in the rate of combustion and amount of coal feed for 3 to $3\frac{1}{2}$ hours.

The amount of coal fed in the kiln at any time should be especially suitable for the material for the time being in the clinkering zone. Owing, however, to the possibility of a frequent change in the amount of material passing into the clinker zone, the coal-feed equipment should provide for easy and quick adjustment within fine limits. The air supply should also be easily adjustable; this might prove more difficult, but it would be equally effective to adjust the damper,

and a suitable fitting should be provided for this duty. In adjusting the coal and air supply, or the damper, every effort should be made to obtain a very hot, lazy flame as a means of attaining the high temperature referred to and which alone will result in high heat efficiency.

Summary.

The production of clinker in the rotary kiln calls for the highest flame temperature obtainable: 2,500 deg. F. or a little higher is the usual flame temperature, but 2,850 deg. F. is possible under best conditions and every effort should be made to obtain this higher figure.

The highest temperature calls for (1) the minimum amount of excess air; (2) the highest possible temperature of the combustion air; (3) perfect mixing of the gases; and (4) good combustion-zone conditions.

The most economic amount of excess air, based on fuel of 12,600 B.T.U.'s per lb., is 5 per cent.; this excess allows for any reasonable variation in the heat value of the fuel, and also for imperfect mixing of the combustion gases. Leakage of air should be avoided.

The temperature of the combustion air during its passage through a normal cooler is 400 deg. F., but any reasonable increase upon this figure would be a definite advantage; if the increase is considerable some detail adjustments may prove necessary. All combustion air should be passed through the clinker cooler.

The calculated increase in flame temperature (all other conditions remaining the same) would be, say, 75 deg. F. for each 100 deg. F. increase in that of the combustion air; the actual increase, however, might be somewhat less than the calculated figure.

Better combustion zone conditions may possibly be obtained by shielding the flame and the hottest local area from the chilling effect of cold rays emanating from uncovered and unlined air-cooled surfaces.

The combustion zone or area is small and should not be overloaded, otherwise it will be impossible to attain efficient combustion conditions. An overloaded zone may result in combustion being continued for some distance up the kiln, and high-grade heat will be used where it cannot be taken full advantage of; it will actually be used for duty that low-grade heat would serve equally well.

Owing to heat loss, caused by frequent change of conditions and temperature, continuous running and consistent operation are important.

No reference has been made to the rate or intensity of combustion, the velocity of the gases as they pass through the combustion zone, the volume of the combustion zone, or the duty of these various parts in the combustion process. It may be stated, however, that, as far as can be seen at present, there is no likely combination of high rate of combustion with high efficiency or low fuel consumption; either of these results alone is possible, but not in combination; a compromise is practicable, but at the expense of one or both phases.

Phase-Equilibria Studies Involving Potash.

THIS investigation by Mr. William C. Taylor is one of a series of studies undertaken by the United States National Bureau of Standards for the purpose of determining the manner in which K_2O is combined in Portland cement clinker. The research on the phase-equilibrium relations of $2CaO.SiO_2$ and $K_2O.CaO.SiO_2$ was made after preliminary examinations had shown that the compound $K_2O.Al_2O_3$ was unstable in the presence of $3CaO.SiO_2$ and $2CaO.SiO_2$. The compounds $2CaO.SiO_2$ and $K_2O.CaO.SiO_2$ were found to form a binary system containing one additional compound having a probable composition of $K_2O.23CaO.12SiO_2$. Thermal, optical and X-ray diffraction data are presented and a temperature concentration diagram has been constructed. The stability of the compound $K_2O.23CaO.12SiO_2$ in Portland cement clinker prepared only from K_2O , CaO , Al_2O_3 , SiO_2 , and Fe_2O_3 has been indicated. While no evidence of any other compound of potash in such preparations, heated and cooled under equilibrium conditions, has been obtained, it has been indicated, in the continuation of this series of investigations, that SO_3 present in a mixture combines with K_2O to form K_2SO_4 . This compound has since been observed in many commercial clinkers.

An introductory note states that a prominent part of the programme of the Portland Cement Association Fellowship at the National Bureau of Standards has, for several years, been devoted to the purpose of establishing the constitution of Portland cement clinker. Numerous other workers also have contributed largely to the present general conception of the constitution, which is fairly definite with reference to the principal oxides, namely, CaO , MgO , SiO_2 , Al_2O_3 and Fe_2O_3 . In order to make this concept more definite, it is necessary to have knowledge not only of the phase equilibrium relations among the principal oxides, but also those of K_2O , Na_2O , SO_3 , and other minor oxides.

The complications usually attending the study of multiple-component systems may be reduced in investigations of the effects of the minor oxides on clinker constitution as follows: First, by conducting a series of investigations on binary and ternary systems in which one of the minor oxides and one or more of the major oxides appear; secondly, by examining the products of reactions involving one of the minor oxides and one or more of the established clinker compounds. Potash was the minor oxide used in the series of studies reported in the present paper.

Brownmiller¹ found that $K_2O.Al_2O_3$ is the only compound of potash which is stable at the liquidus, in the portion of the K_2O - CaO - Al_2O_3 system which he studied. The present author² showed that the compound $K_2O.Al_2O_3$ is stable in the presence of $4CaO.Al_2O_3.Fe_2O_3$, and, furthermore, that $K_2O.Al_2O_3$ can exist in the presence of $2CaO.Fe_2O_3$, which may be present in clinkers having an $Al_2O_3:Fe_2O_3$ ratio less than 0.64. Obviously the stability or instability of $K_2O.Al_2O_3$ in the presence of other cement compounds, such as $2CaO.SiO_2$ and $3CaO.SiO_2$, must be determined; and if new potash compounds should be formed,

their phase-equilibrium relations to the various clinker constituents must also be investigated.

The choice of the system $2\text{CaO} \cdot \text{SiO}_2\text{-K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ for investigation was made after preliminary work indicated that $\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3$ reacts with $2\text{CaO} \cdot \text{SiO}_2$ and $3\text{CaO} \cdot \text{SiO}_2$ to form an unidentified potash-lime-silica compound and that $\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3$ and $2\text{CaO} \cdot \text{SiO}_2$ do not form a binary system. Mixtures along the join $2\text{CaO} \cdot \text{SiO}_2\text{-K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ in the system $\text{K}_2\text{O-CaO-SiO}_2$ are just beyond that portion of the system investigated by Morey, Kracek and Bowen.³ These investigators report that the primary phase $2\text{CaO} \cdot \text{SiO}_2$ appears in the field adjacent to that of $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ and that "there is some indication that the index of $2\text{CaO} \cdot \text{SiO}_2$ in this region is lowered slightly by solid solution, but this is not certain." Thus the possibility remains that some compound exists which is similar to $2\text{CaO} \cdot \text{SiO}_2$ in appearance, but between $2\text{CaO} \cdot \text{SiO}_2$ and $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ in composition. In preliminary experiments by the author, free CaO was always found by microscopical examination in heated charges when mixtures of CaO and SiO_2 in molar ratios greater than 2:1, respectively, had been added to $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$.

Experimental Method.

For the study of the system $2\text{CaO} \cdot \text{SiO}_2\text{-K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$, and for the preliminary experiments reported in part in this paper, the following compounds were prepared: $2\text{CaO} \cdot \text{SiO}_2$ (largely in the gamma form), $3\text{CaO} \cdot \text{SiO}_2$, $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$, $\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3$, $3\text{CaO} \cdot \text{Al}_2\text{O}_3$, and $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$. The exact compositions were determined by chemical analyses and microscopical examinations. Various mixtures of these compounds were intimately ground in an agate mortar and then heated in open platinum boats in an electric furnace at about 1,250 deg. C. for half an hour. Losses of potash by volatilisation from these preparations were determined by weight differences before and after heating, and compensating additions of K_2O were made. The heated preparations were reground and placed in sealed bottles, which were shaken to ensure a high degree of homogeneity. Small charges for thermal study were taken from these base samples, the general procedure, previously outlined,^{1 2} being followed.

Charges were examined microscopically by two different methods, namely, powder specimens viewed by transmitted light, and polished thin sections which were viewed by both transmitted and reflected light.

Phase Equilibria.

Mixtures of $2\text{CaO} \cdot \text{SiO}_2$ and $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ throughout the entire range were studied. The compound $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ persisted in the completely crystallised charges until the $2\text{CaO} \cdot \text{SiO}_2\text{:K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ ratio of 9:1 was reached. In this charge only one phase, with the exception of about 0.5 per cent. of extraneous material, existed. The amounts of this phase had been increasing with increasing ratios of $2\text{CaO} \cdot \text{SiO}_2$ to $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ in this series of changes. The ratio of 9:1 by weight, corresponding to a molar ratio of 11:1, indicated that 11 molecules

¹ L. T. Brownmiller, *Am. J. Sci.* 29, 260 (1935).

² Wm. C. Taylor, *J. Research NBS* 21, 315 (1938) RP1131.

³ G. W. Morey, F. C. Kracek and N. L. Bowen, *J. Soc. Glass Tech.* 14, 149 (1930).

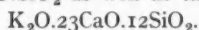
of $2\text{CaO} \cdot \text{SiO}_2$ combined with 1 molecule of $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ to form a new compound $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ containing 4.48 per cent. of K_2O , 61.28 per cent. of CaO , and 34.25 per cent. of SiO_2 . The X-ray diffraction pattern obtained from this charge, while not very sharp, differed distinctly from the pattern of $\beta\text{-}2\text{CaO} \cdot \text{SiO}_2$ and $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$. Although the evidence points to the probable existence of the compound $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$, it is recognised that points on a liquidus curve near $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ would be necessary to establish the composition. The possibility of limited solid solution of $2\text{CaO} \cdot \text{SiO}_2$ and $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ with a compound having a composition slightly different from $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ remains. The temperatures which would be required for the location of the liquidus curve in this portion of the system are far beyond the limits of the furnace employed. McMurdie,⁴ working independently, also came to the conclusion that a ternary compound having the composition $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ probably exists in the K_2O - CaO - SiO_2 system.

TABLE I.—THERMAL DATA RELATIVE TO THE SYSTEM $2\text{CaO} \cdot \text{SiO}_2$ — $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$.

Composition		Temperature of quench	Examination
C_2S	KCS		
%	%	° C	
0	100	1,625	Glass; small amount of crystalline material.
		1,617	All crystalline. (mp. 1,630° C, according to Morey, Kracek, and Bowen.)
		1,627	Glass.
5	95	1,619	KCS; glass.
		1,594	KCS; KC_2S_{11} ; trace of glass
		1,598	Glass.
8	92	1,590	KC_2S_{11} ; KCS
		1,650	Glass.
10	90	1,637	Do.
		1,625	Small amount of KC_2S_{11} ; glass
		1,598	KC_2S_{11} ; KCS; glass
		1,670	Glass.
15	85	1,660	Small amount of KC_2S_{11} ; much glass
		1,600	KC_2S_{11} ; glass.
		1,590	KC_2S_{11} ; KCS
20	80	1,660	KC_2S_{11} ; glass.
		1,598	KC_2S_{11} ; KCS; slight amount of glass
		1,590	KC_2S_{11} ; KCS.
30	70	1,650	KC_2S_{11} ; glass
		1,618	Do.
		1,640	Do.
40	60	1,612	Do.
		1,598	KC_2S_{11} ; KCS; slight amount of glass.
		1,690	KC_2S_{11} ; KCS.
		1,640	KC_2S_{11} ; glass.
50	50	1,600	Do.
		1,590	KC_2S_{11} ; KCS; trace of glass.
		1,580	KC_2S_{11} ; KCS.
		1,600	KC_2S_{11} ; glass.
85	15	1,600	Do.
		1,590	KC_2S_{11} ; KCS
		1,520	KC_2S_{11} ; about 7% of KCS
88	12	1,660	KC_2S_{11} ; glass.
		1,520	KC_2S_{11} ; about 2% of KCS.
		1,550	Except for trace of glass, one crystalline phase
90	10	1,600	One crystalline phase.
		1,520	Do.
91.4	8.6	1,628	Apparently one crystalline phase.
		1,520	Do.
95	5	1,628	Do.
		1,555	Do.
98	2	1,628	Do.
		1,555	Do.
100	0	-----	(mp. 2,130° C, according to Rankin and Wright).

⁴ H. F. McMurdie, Private Communication.

The thermal data for the system are given in *Table 1*.^{*} It will be seen from the table that no glass was found in any of the quenched samples containing more than 90 per cent. of $2\text{CaO} \cdot \text{SiO}_2$ and that the charges apparently were composed of only one phase in each case. The refractive indexes of these charges increased as the ratio of $2\text{CaO} \cdot \text{SiO}_2 : \text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ increased, and it became increasingly difficult to distinguish the material from $\beta\text{-}2\text{CaO} \cdot \text{SiO}_2$. Polysynthetic twinning, characteristic of $\beta\text{-}2\text{CaO} \cdot \text{SiO}_2$ which had at some time been in the α state, was common. These results indicated the possibility that the compound $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ passed into solid solution with $\beta\text{-}2\text{CaO} \cdot \text{SiO}_2$ in all proportions. The X-ray diffraction pattern obtained from the charge composed of 91.4 per cent. of $\beta\text{-}2\text{CaO} \cdot \text{SiO}_2$ and 8.6 per cent. of $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$, however, showed the lines characteristic of $\beta\text{-}2\text{CaO} \cdot \text{SiO}_2$ as well as those characteristic of



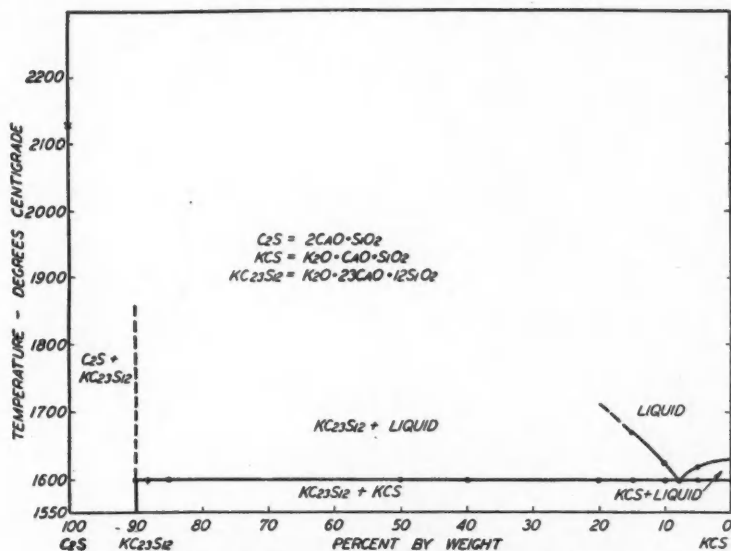
The lines of the latter compound were considerably weaker than those in the X-ray photograph of the charge composed of 90 per cent. of $2\text{CaO} \cdot \text{SiO}_2$ and 10 per cent. of $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$. Since the X-ray data ruled out the possibility of continuous solid solution, it was assumed that intimate crystallisation of the two compounds had occurred, and because of the similarity in optical properties the product appeared as one phase. This was all the more likely since no liquid was formed in any case from which one of the phases could crystallise. The complexity of the twinning also was a factor in rendering identification more difficult.

None of the charges which contained more than 15 per cent. of $2\text{CaO} \cdot \text{SiO}_2$ was melted completely at the temperatures employed (see *Table 1*). Sufficient data were obtained, however, to indicate that $2\text{CaO} \cdot \text{SiO}_2$ and $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ constitute a binary system containing one intermediate compound having the probable composition $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$. The composition of the eutectic formed by $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ and $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ was 8.9 per cent. of the former, 91.1 per cent. of the latter (8 per cent. of $2\text{CaO} \cdot \text{SiO}_2$ and 92 per cent. of $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$). The eutectic melted at $1,598 \text{ deg.} \pm 10 \text{ deg. C.}$ The liquidus temperature of the charge containing 15 per cent. of $2\text{CaO} \cdot \text{SiO}_2$ and 85 per cent. of $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$ was $1,670 \text{ deg. C.}$ This temperature was about the maximum obtainable in the furnace employed; hence the thermal data obtained for the system were incomplete beyond this point. The incomplete temperature-concentration diagram is given in *Fig. 1*.

A much larger quantity of the compound $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$ was prepared in a horizontal electric furnace.⁵ In order to overcome the difficulties of adjusting the K_2O content of the preparation, caused by the increase in volatilisation of K_2O during repeated heat treatments in open platinum boats, the following procedure was adopted, after many preliminary tests. To the powdered CaCO_3 , $\text{K}_2\text{O} \cdot \text{SiO}_2$ and SiO_2 , mixed in the proportions $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$, there was added a weighed quantity of potassium oxalate equal in K_2O content to that previously introduced as $\text{K}_2\text{O} \cdot \text{SiO}_2$. Thus the total K_2O content of the unheated

^{*} In the tables the following abbreviations apply: C_2S for $2\text{CaO} \cdot \text{SiO}_2$, KCS for $\text{K}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$, $\text{KC}_{23}\text{S}_{12}$ for $\text{K}_2\text{O} \cdot 23\text{CaO} \cdot 12\text{SiO}_2$, C_3S for $3\text{CaO} \cdot \text{SiO}_2$, C_3A for $3\text{CaO} \cdot \text{Al}_2\text{O}_3$, C_4AF for $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$.

⁵ W. C. Hansen and R. H. Bogue, *Ind. Eng. Chem.* 19, 1260 (1927).

Fig. 1.—The System $2CaO \cdot SiO_2 - K_2O \cdot CaO \cdot SiO_2$.

mixture was twice that required. The K_2O content of the heated preparation was determined directly by chemical analysis, and not by loss of weight. The mixture was subjected to a preliminary heat treatment of 1,250 deg. C. for eight minutes and then finely ground. Three successive heat treatments at 1,500 deg. C. for eight minutes were made with intermediate fine grinding, microscopical examination and complete chemical analysis. The final product consisted almost entirely of a single crystalline phase, apparently identical with that found in the small heated charge of a 9:1 $2CaO \cdot SiO_2 : K_2O \cdot CaO \cdot SiO_2$ mixture. In addition to this crystalline phase, a microscopical examination showed the presence of small quantities of extraneous materials. They consisted of a few grains of CaO , occasional thin veins of an isotropic material having a low index of refraction, and a number of small specks of an unidentifiable substance.

(To be concluded.)

**SUPER
REFRACTORIES**
for
**CEMENT
KILNS**

ALITE No. 1. 68% ALUMINA
Refractory Standard 3250° Fahr.

ALITE B. 57% ALUMINA
Refractory Standard 3180° Fahr.

ALITE D. 41% ALUMINA
Refractory Standard 3150° Fahr.

E. J. & J. PEARSON, LTD.,
STOURBRIDGE, ENG.

Two Types of Air Separator.

Two types of air separators are made by Messrs. Edgar Allen & Co., Ltd. Type A is designed for separating out fine materials as ordinarily required in commercial processes, and type B is for finer materials.

The machine (*Fig. 1*) consists of an outer casing of sheet-iron, circular in

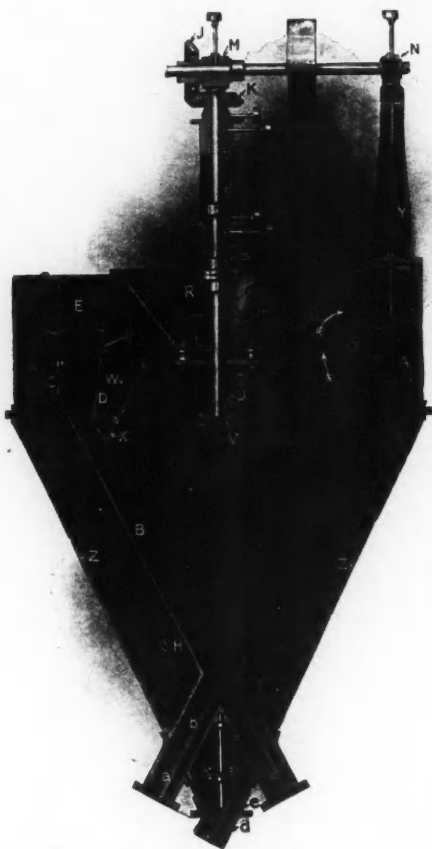


Fig. 1.—Sectional View of Type A Separator.

form, together with an inner casing, separate from each other, for collecting the fine and coarse materials respectively. Above the inner casing (B), and fitted on a vertical spindle, is a fan with blades (E) which, when revolved, induce a current of air. Fixed on the same spindle is a disc (E'), which spreads the material being treated in a thin stream all round towards a fixed hood (D) directly



CEMENT MAKING MACHINERY

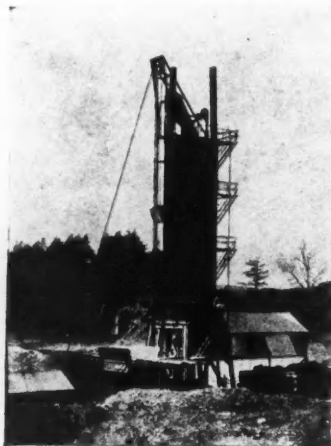
PATENT SLURRY DESICCATORS. ROTARY KILNS
WITH PATENT RECUPERATORS. AIR-SWEPT
COAL PLANTS. COMPOUND BALL AND TUBE
GRINDING MILLS. COMPLETE CRUSHING PLANTS.
ROTARY DRYERS. MIXERS AND AGITATORS, ETC.

*The illustration shows three 6' 6" dia. x 36' 0" long
Compound Tube Mills, part of a complete Cement
Works in Hong Kong manufactured and erected by :*

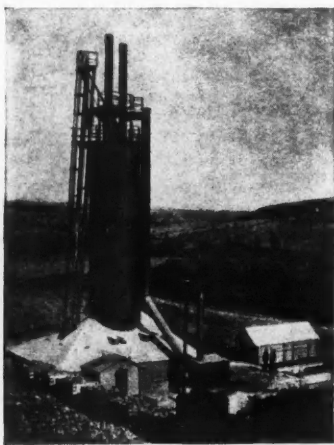
VICKERS - ARMSTRONGS
LIMITED
BARROW-IN-FURNESS

Head Office: VICKERS HOUSE, BROADWAY, LONDON, S.W.1.

CALCINING PLANT



Reconstructed Lime Kiln, capacity increased to 25 tons of burnt product per day.



Lime Kiln, capacity 35 tons of burnt product per day.

Estimates and Designs to
suit the local conditions for

LIME BURNING PLANT.

COMPLETE KILN INSTALLATIONS

of unit capacities ranging from
5 tons to 100 tons per day.

ASHMORE, BENSON, PEASE & CO. LTD.
PARKFIELD WORKS STOCKTON-ON-TEES

below the fan. The current induced by the fan passes upwards and carries with it the fine particles, which are thrown into the outer casing (A). The coarse particles, which are too heavy to be lifted by the current of air, fall into the inner casing (B) and return by the branch pipes (a) to the grinding machine to be further reduced. The degree of fineness of the finished material can be regulated by the speed of the fan, also by the partial closing of a damper (C) fixed between the inner and outer casings, which intercepts the current of air. Material

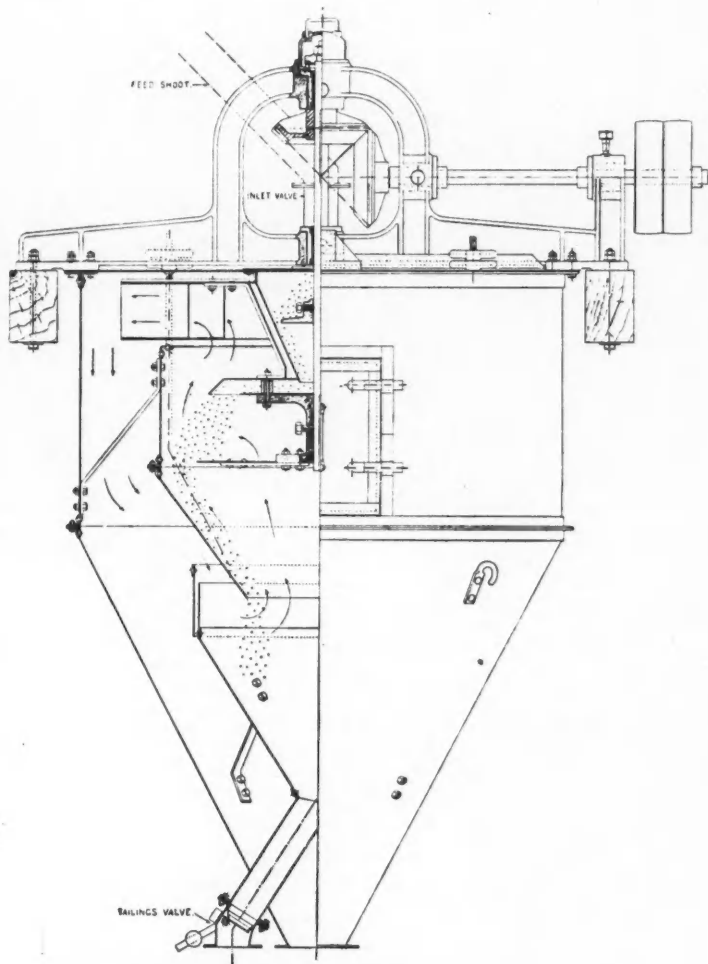


Fig. 2.—Type B Separator.

for treatment in the separator should be delivered by gravity through a spout to the receiving cone (G) and not blown into the machine.

To meet the growing demand for the separation of finer powders such as hydrated lime, etc., a new design of air separator (Fig. 2) has been developed. The operation is similar to the type A design, but the air passages are proportioned to eradicate eddy currents. The arrows indicate the passage of the circulating air which, passing through the incoming material, carries away the fine particles and deposits them in the outer cone, the coarser material falling down through the inner cone and back to the grinding mill by means of the tailings shoot.

Both types of separator are made in diameters of 5ft., 6ft., 7ft. and 9ft.

Among the materials treated are: Ground basic slag, bauxite, burnt lime, calcined flints, cement-clinker, chrome-ore, clay and marl, coke dust, gypsum, hydrated lime, raw limestone, raw shales, aluminous earth, etc.

Repair of a Pump Screw.

A SCREW of a Fuller-Kinyon pump being repaired by welding is shown below. The worn shaft was built up by arc welding and then ground to exact shape. The electrodes used were of the shielded arc type with the characteristics of phosphor bronze; they are known as "Aerisweld," and were supplied by the Lincoln Electric Co., Ltd.

